EVOLVE
FUEL CELL

Manufacturing of Metal Foam Supported SOFCs with Graded Ceramic Layer Structure and Thin-film Electrolyte

Feng Han[1], Robert Semerad[2], and Rémi Costa[1]

[1] German Aerospace Center

[2] Ceraco Ceramic Coating GmbH

DLR

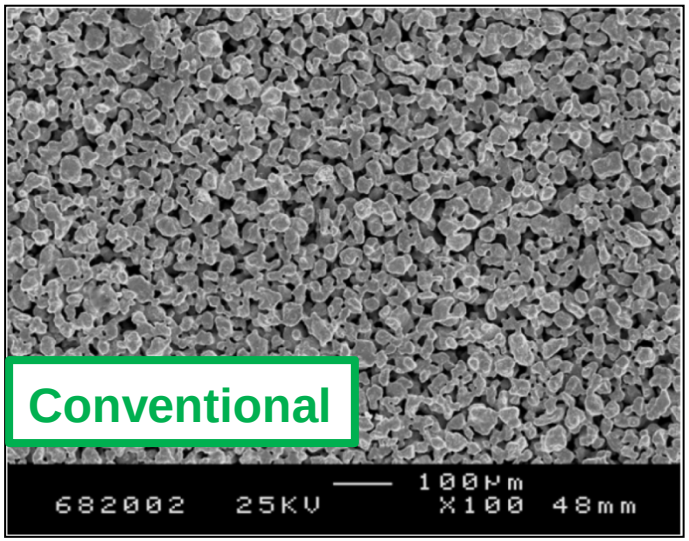
Motivation and Objectives

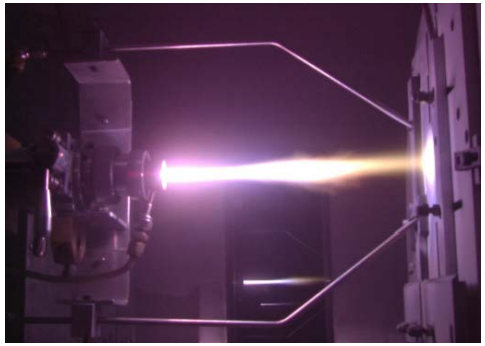
(1) Demonstration of the feasibility of the metal foam supported cell concept and design.

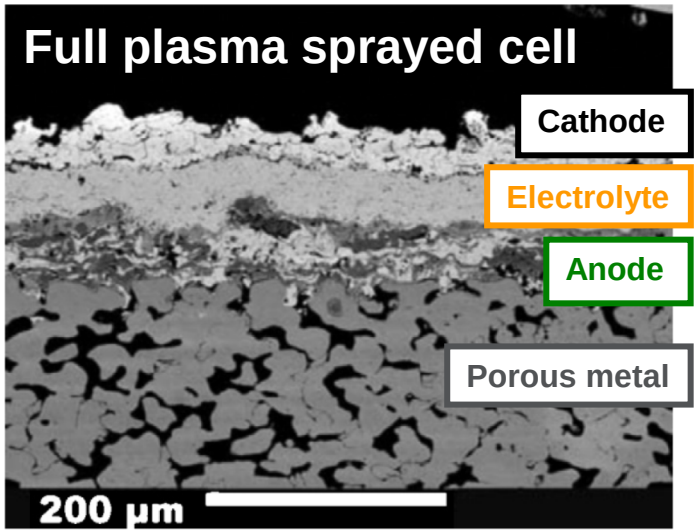
(2) Deposition of gas-tight thin-film electrolyte (~3 μm thick) layers to ensure low ASR

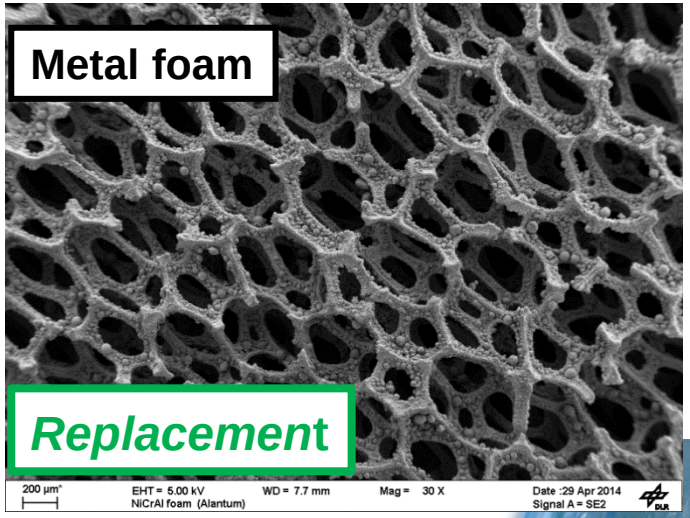
(3) Development of metal foam supported SOFCs in combination with desired materials and catalysts to address issues of SOFC technologies: *sulfur poisonning, redox stability……*

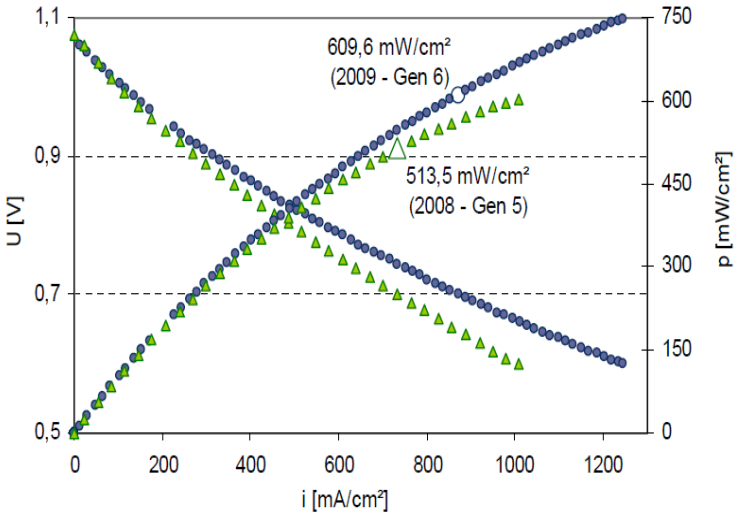
DLR state-of-the-art Metal-supported SOFC (MSC)











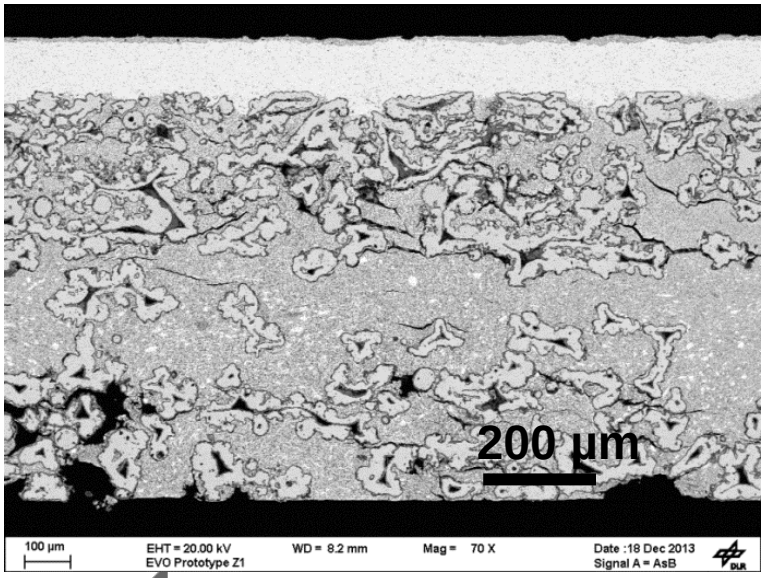
2000 hours tests degradation rate <1.5%/kh

P. Szabo, et. al., ECS Trans. 25 (2) (2009) 175–185.

Electrolyte Manufacturing Routes on MSC

Thick VPS electrolyte
Prototype, low-risk and experienced approach

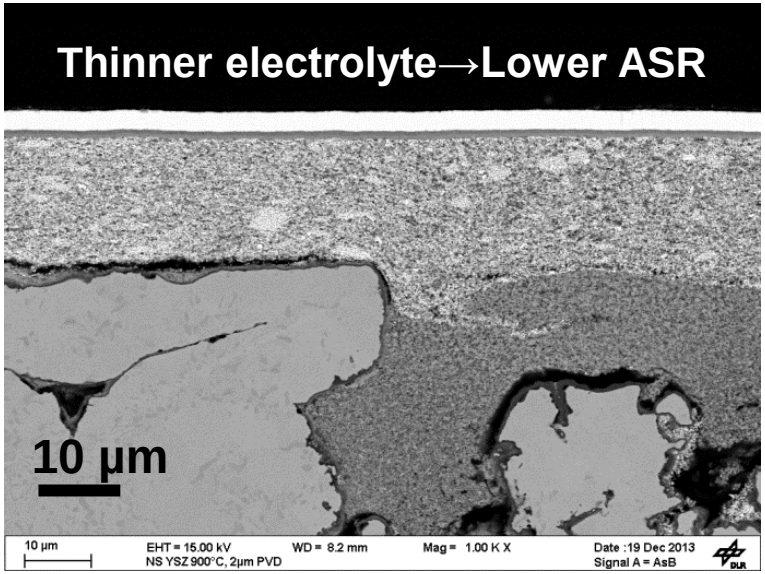
Challenges:
1. Robust substrate
2. Gas-tight electrolyte
3. Efficient functional anode layer



Thin PVD electrolyte
High-risk and high impact approach

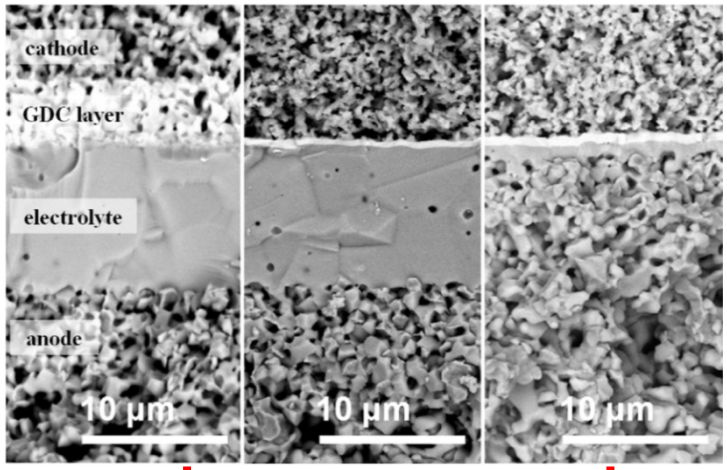
Challenges:
1. Well-defined surface structure
2. Gas-tight thin electrolyte
3. Thermal stability of the multi-layers [1]

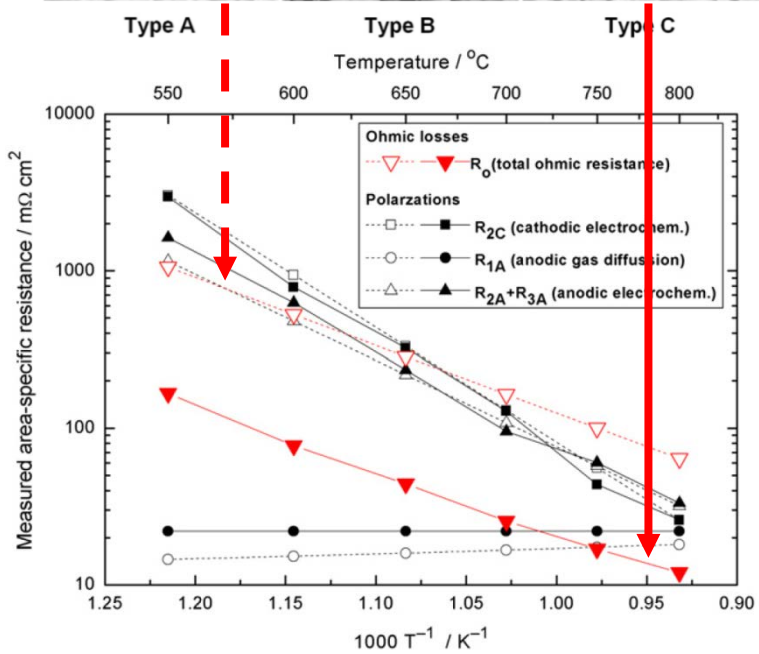
[1] N. J. Escalona, Herstellung von Hochtemperatur-Brennstoffzellen über physikalische Gasphasenabscheidung, PhD thesis, 2008

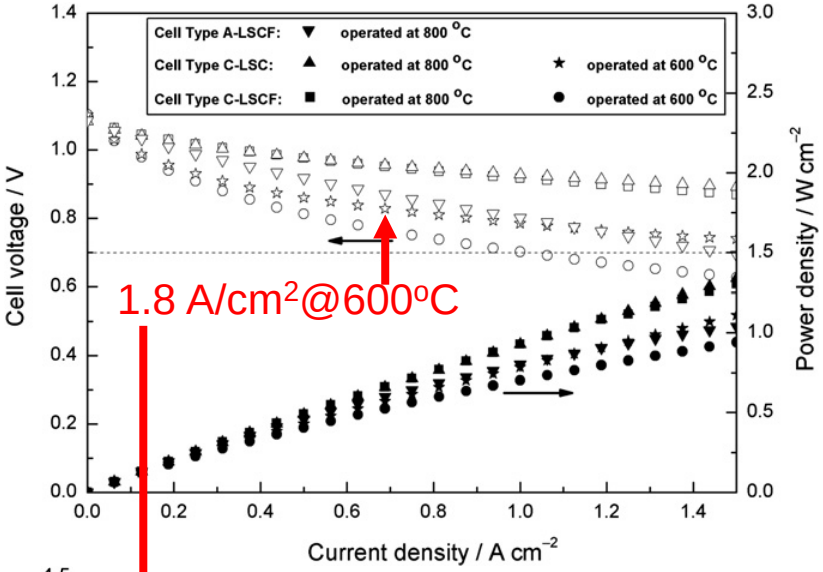


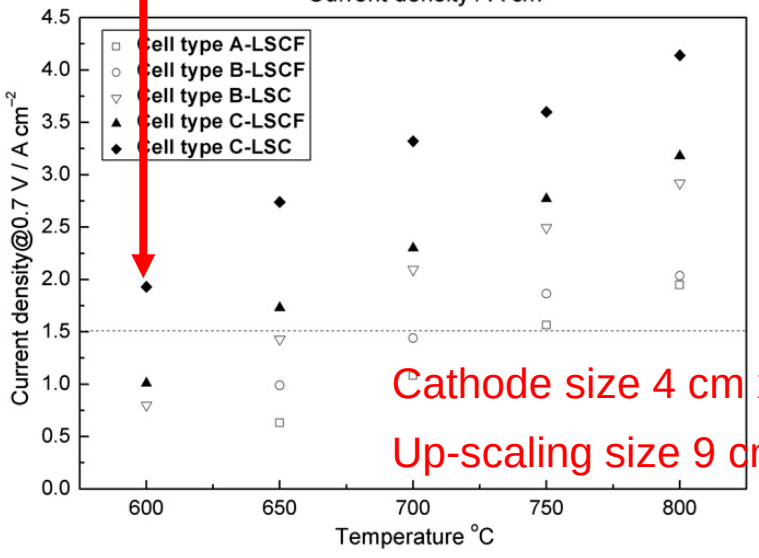
DLR

Performance on ASC cells with thin electrolyte









Cathode size 4 cm x 4 cm

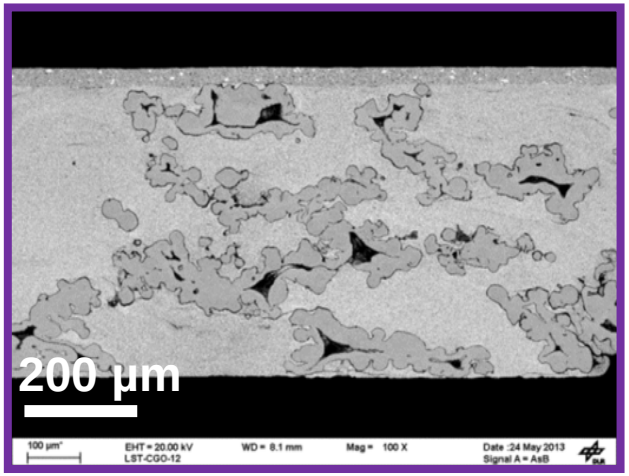
Up-scaling size 9 cm x 9 cm

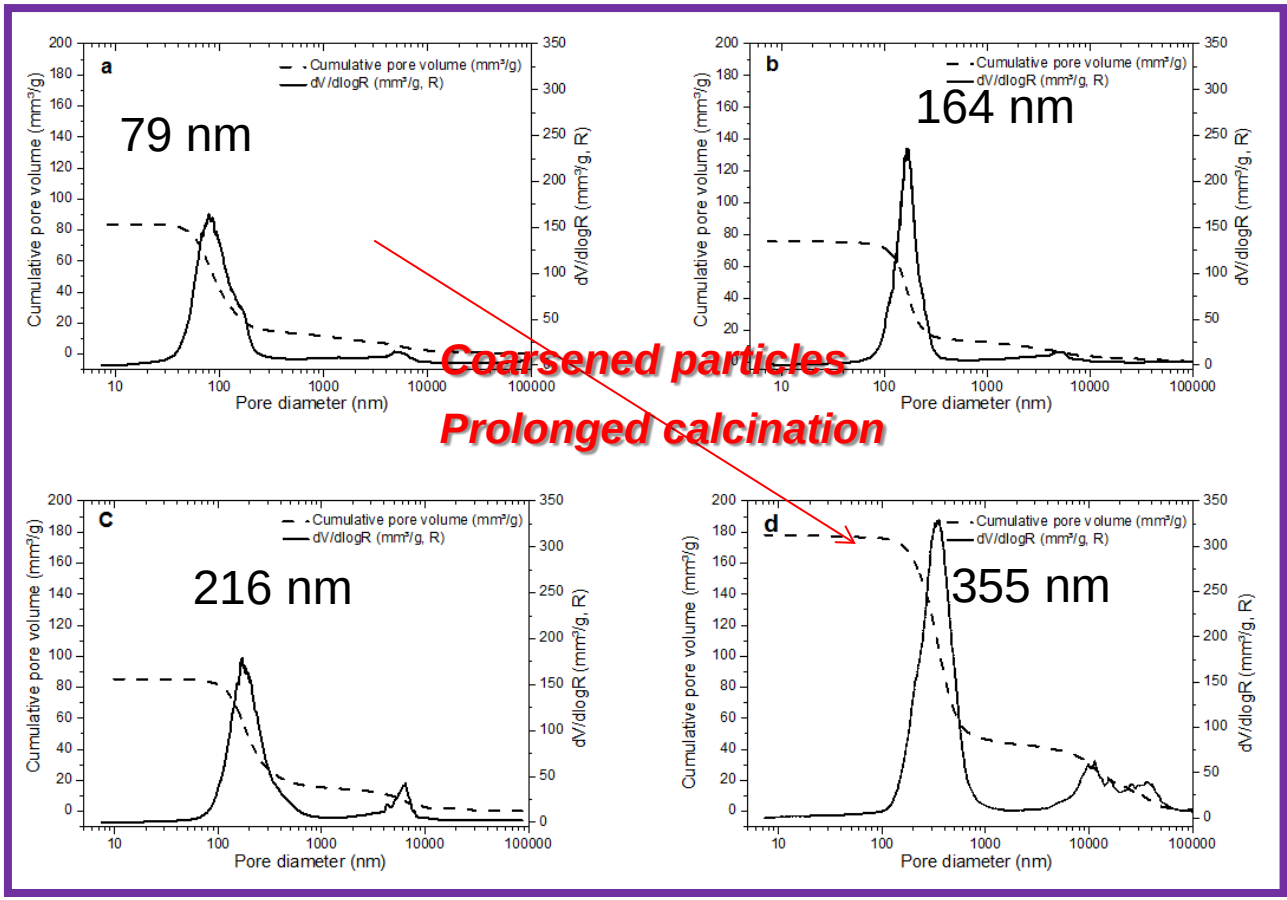
ASR < 0.05 Ω cm² @ 650 °C

F. Han, et. al., J. of Power Sources, 218 (2012)157-162.

Manufacturing of current collecting support

Engineering of pore size



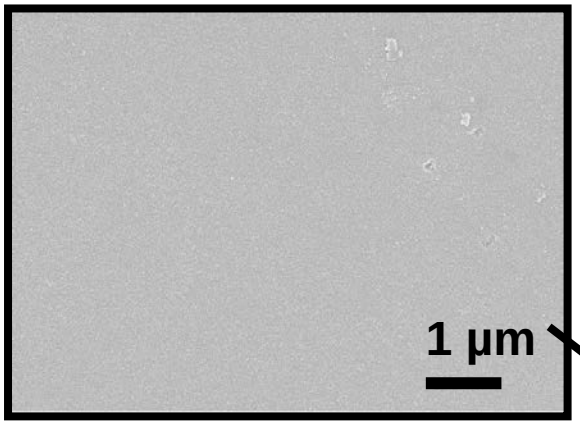


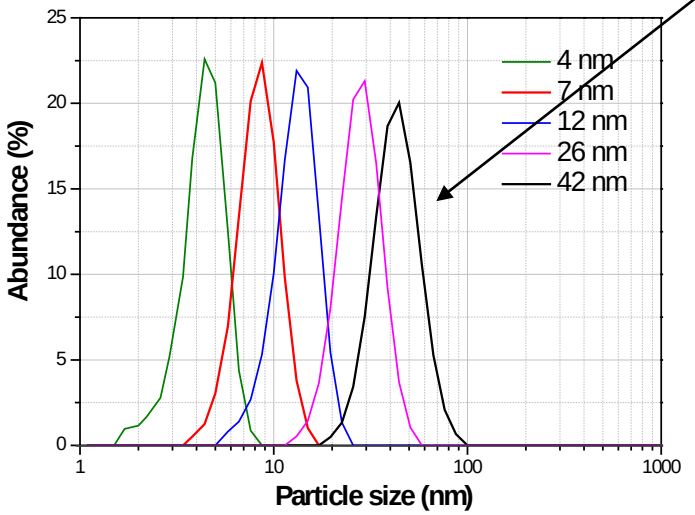
Pore size distribution of calcined NiCrAl alloy substrates with impregnated LST

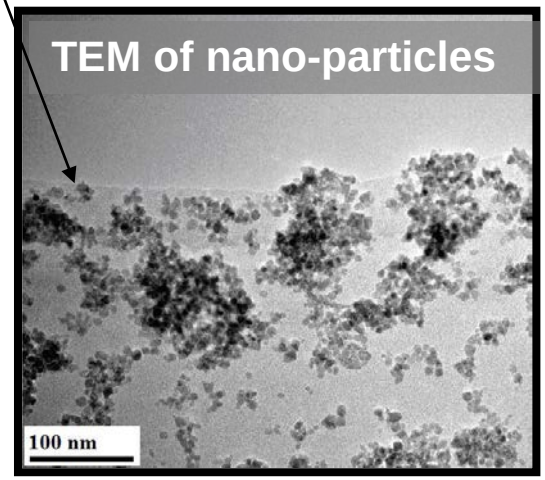
Example of graded layer structure

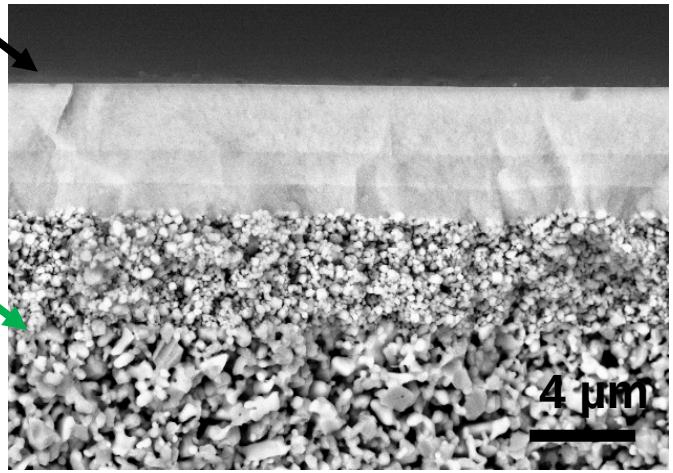
For intermediate layer coating

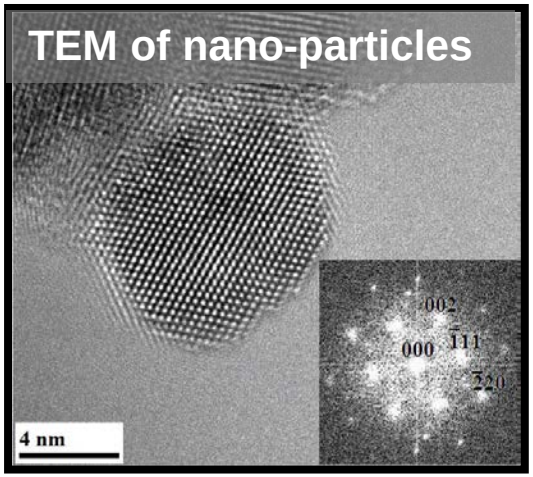
Intermediate YSZ layer
Mesoporous

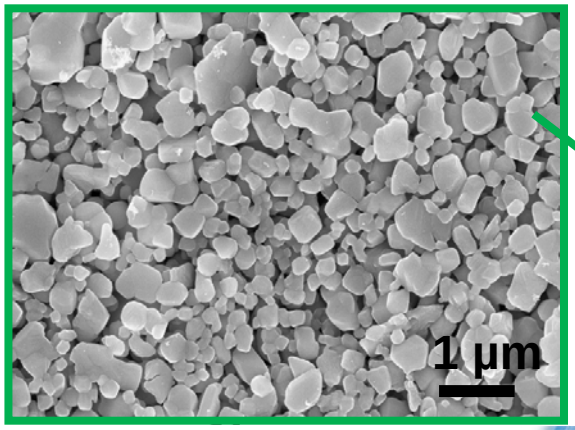








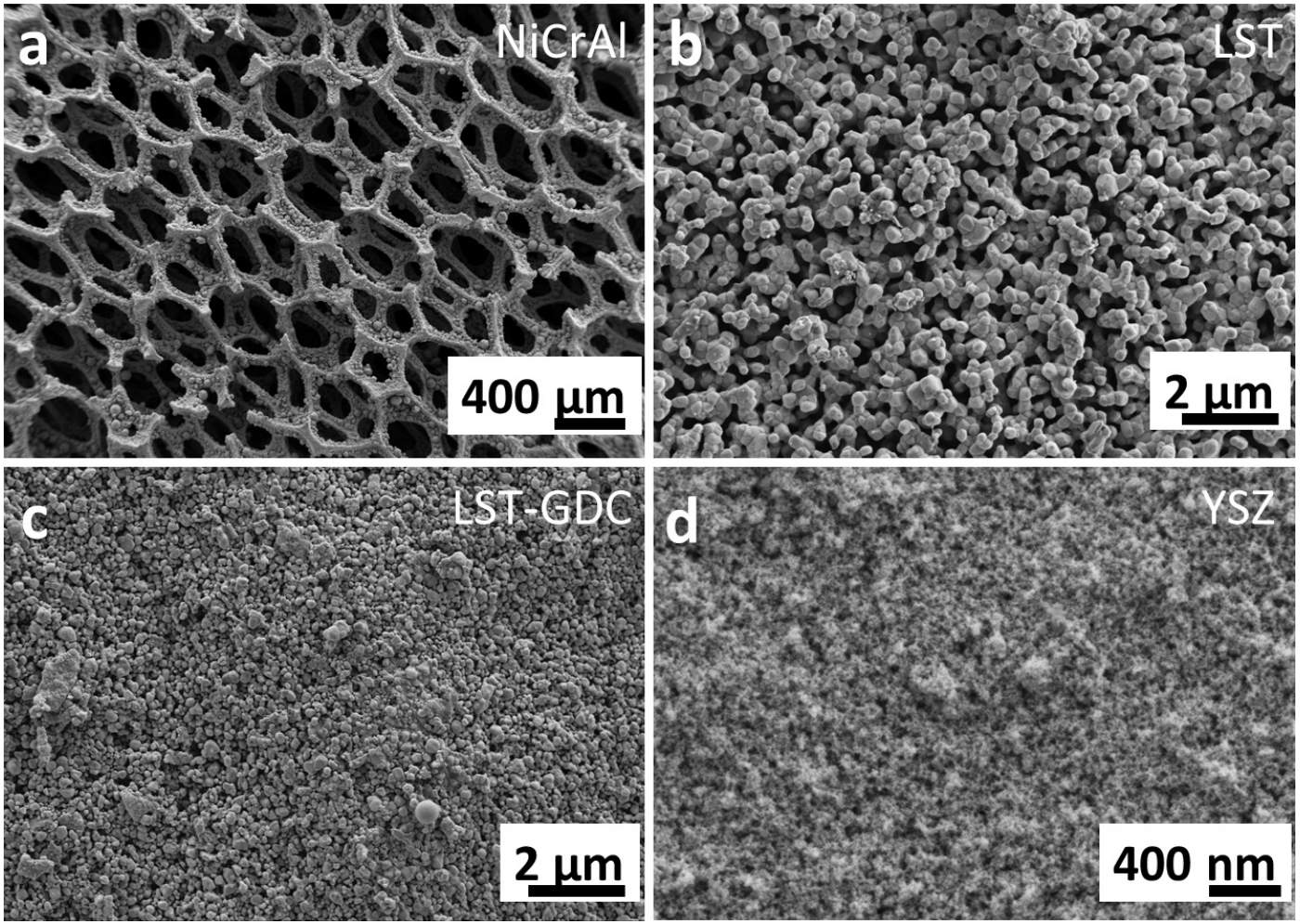




Anode
Macroporous

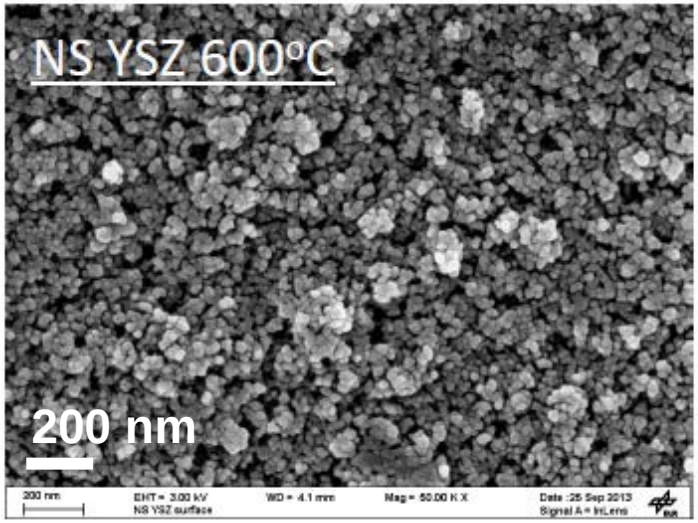
F. Han, et. al., J. of Power Sources, 218 (2012)157-162.

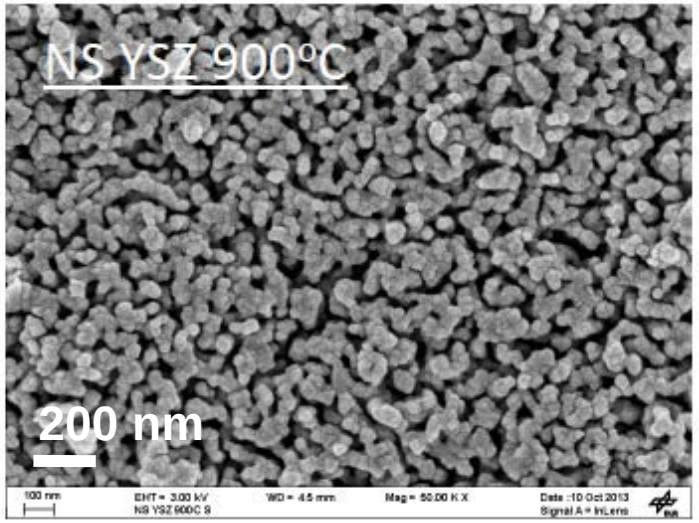
Surface Engineering

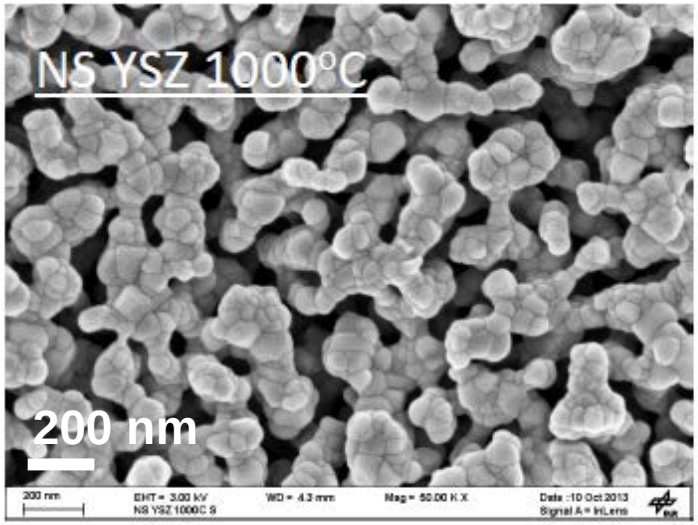


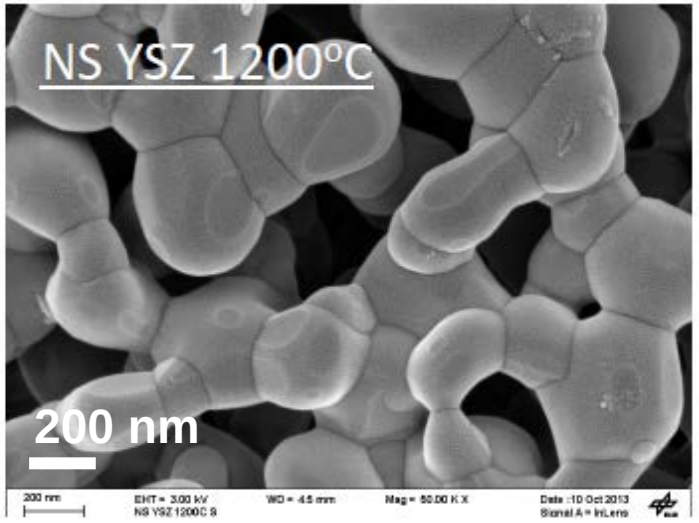
Top view SEM: (a) NiCrAl foam, (b) NiCrAl foam with impregnated LST, (c) LST-GDC anode functional layer, (d) dip-coated YSZ layer

Surface Engineering for supporting PVD GDC

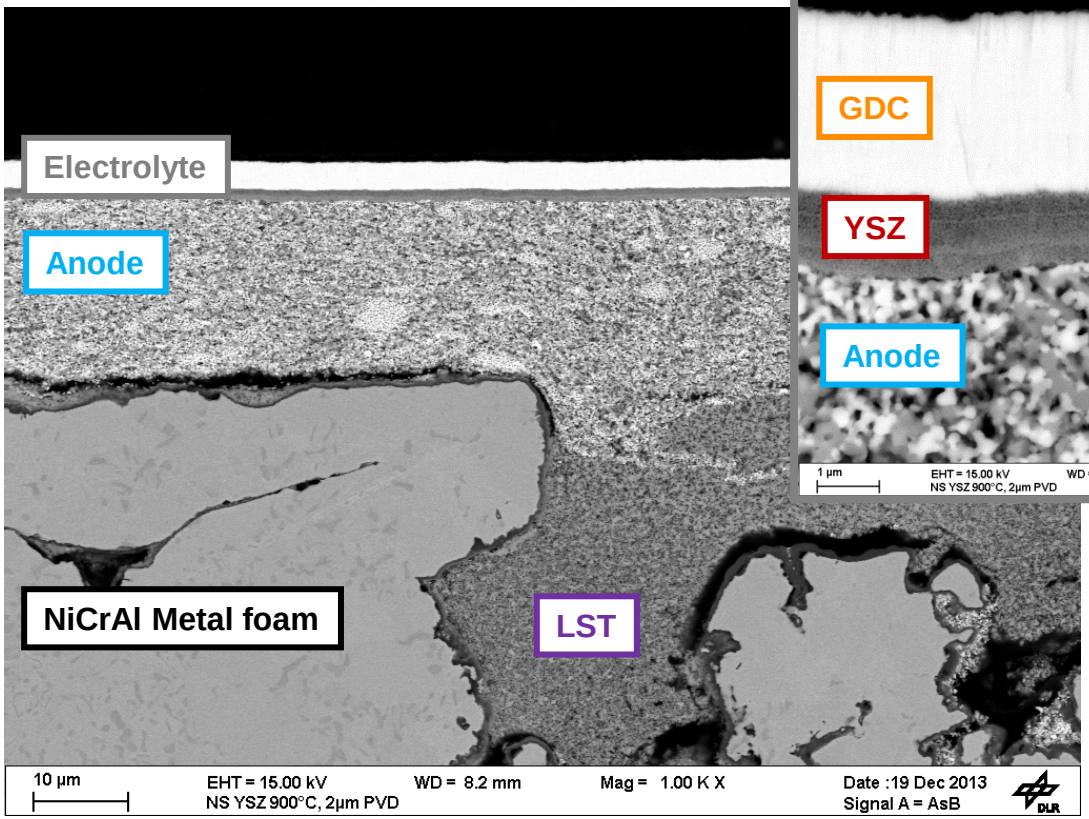


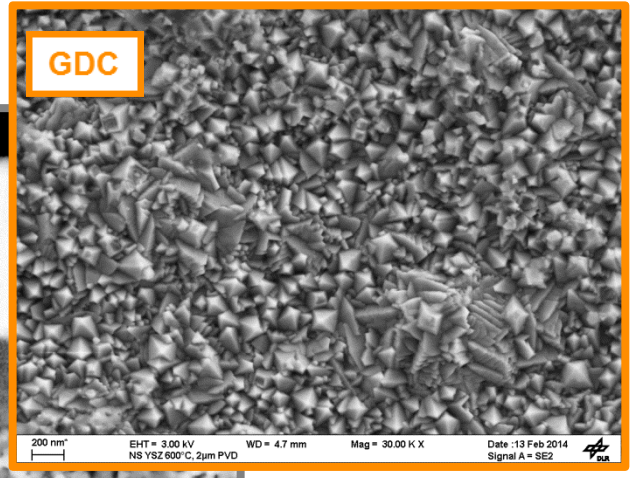


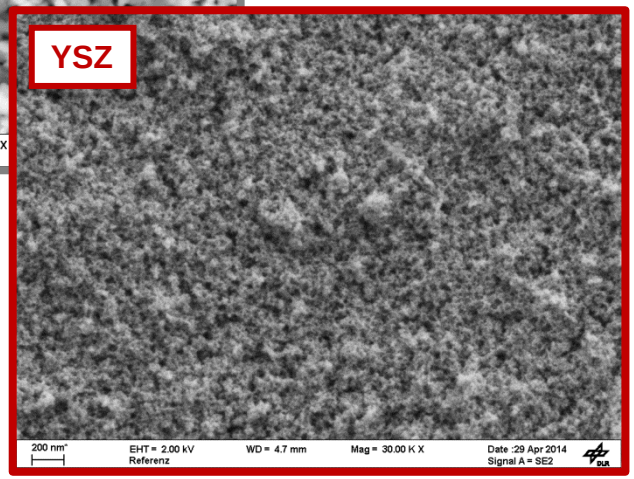


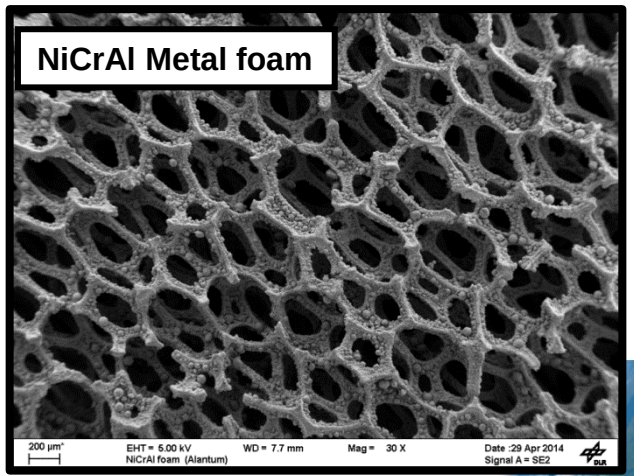


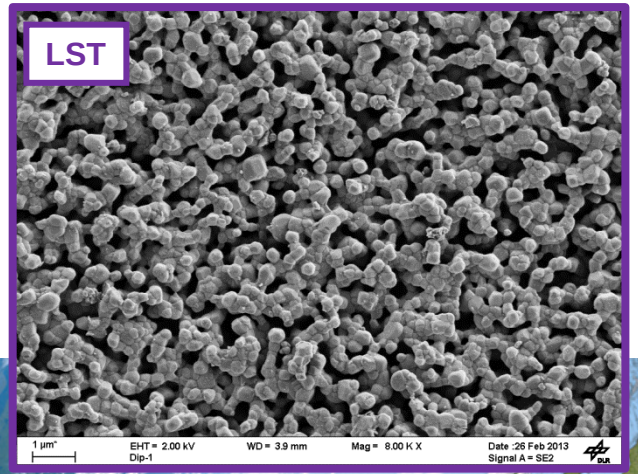
A Way to Thin Electrolyte

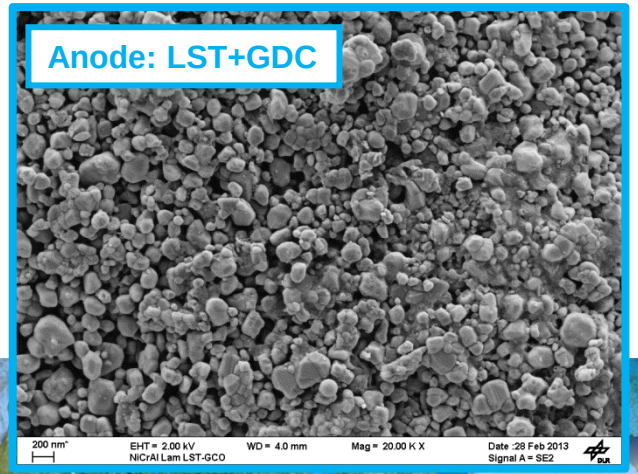




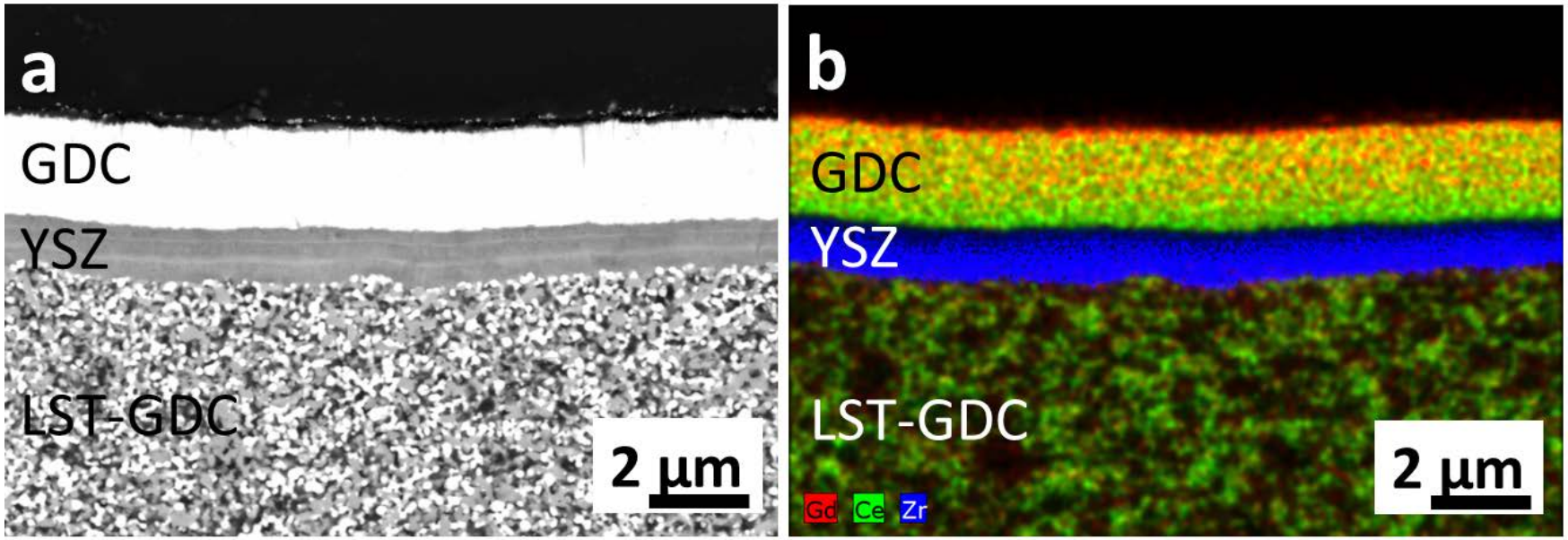






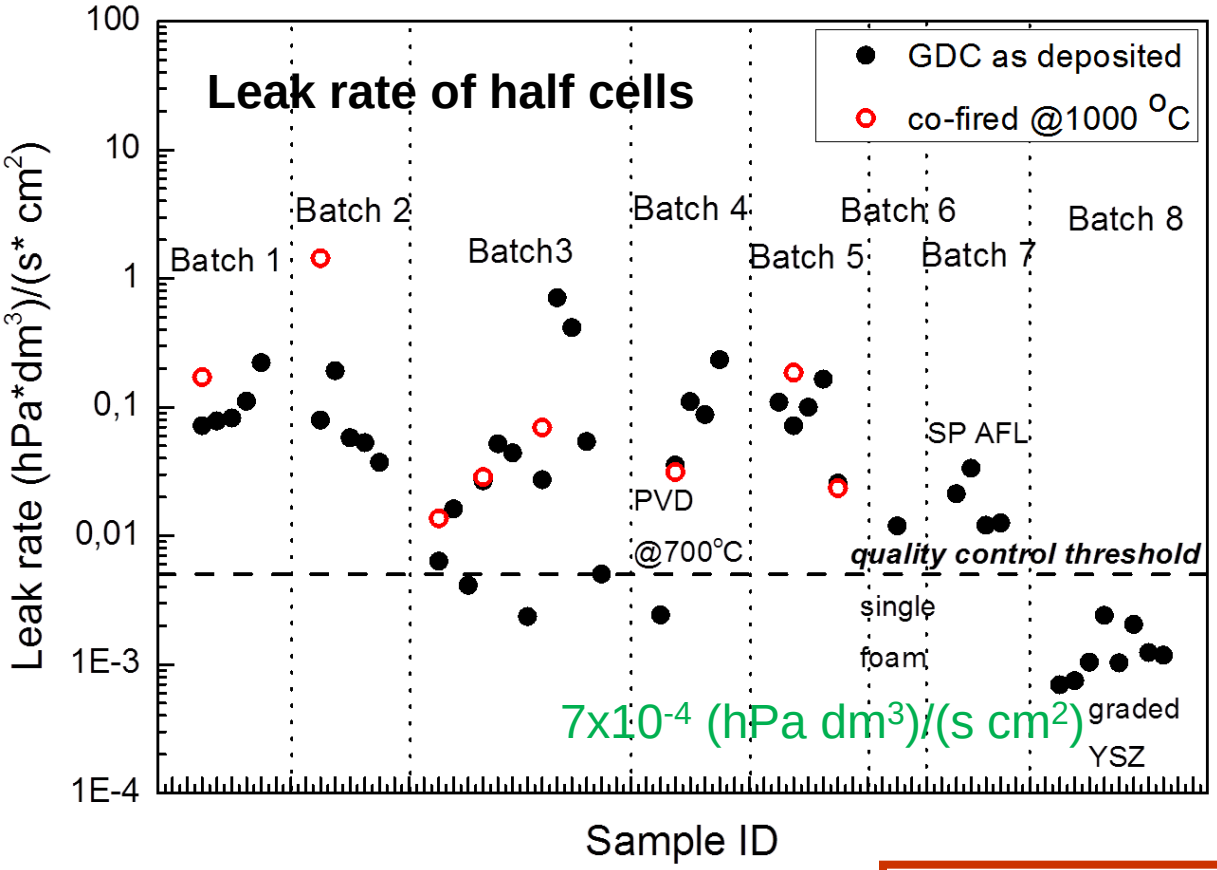


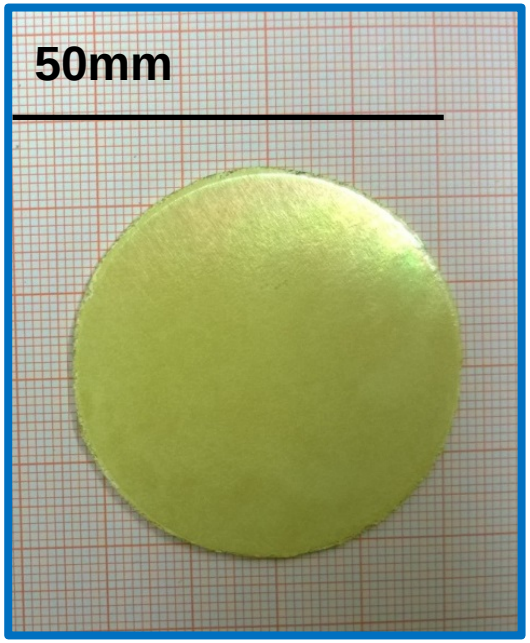
Dense and Gas-tight PVD GDC Electrolyte



SEM of LST-GDC/YSZ/GDC interfaces: (a) cross section, (b) elemental mapping

Leakage rate of half cells with PVD electrolyte



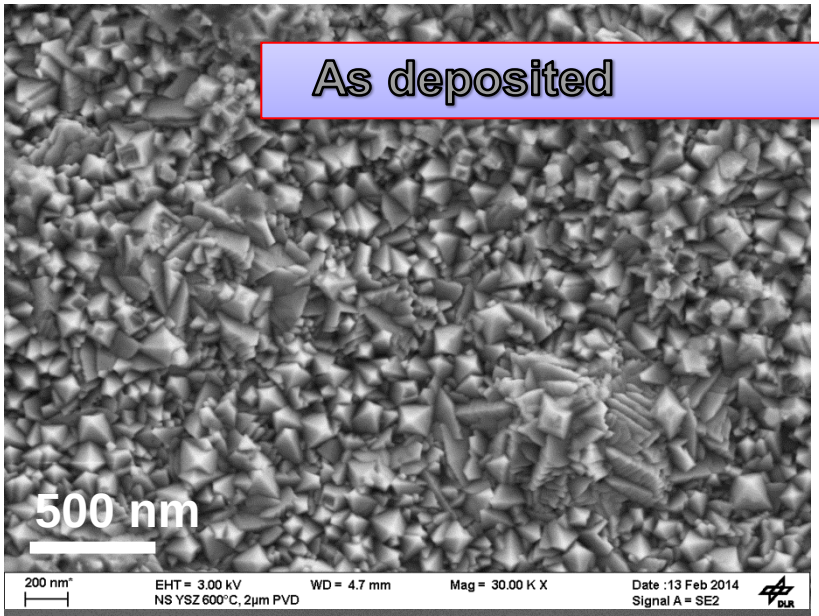


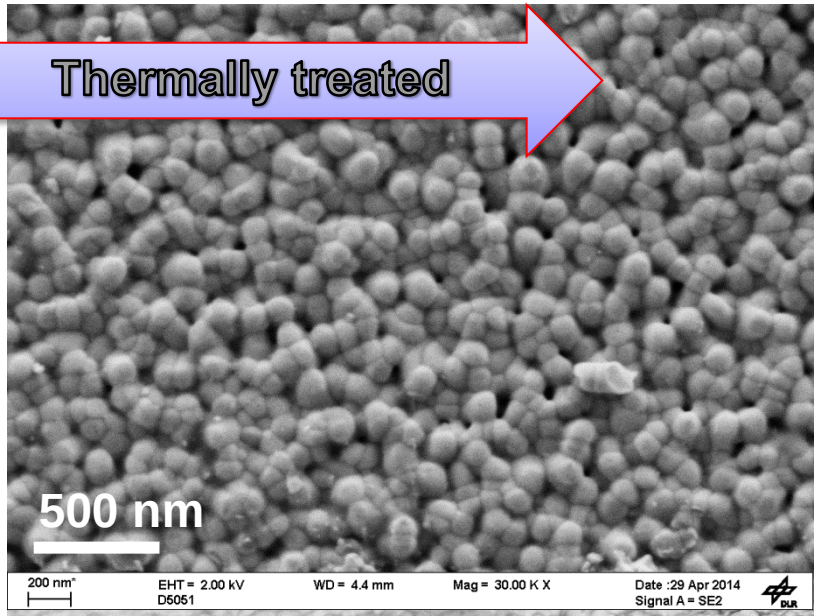
State-of-the-art half cells

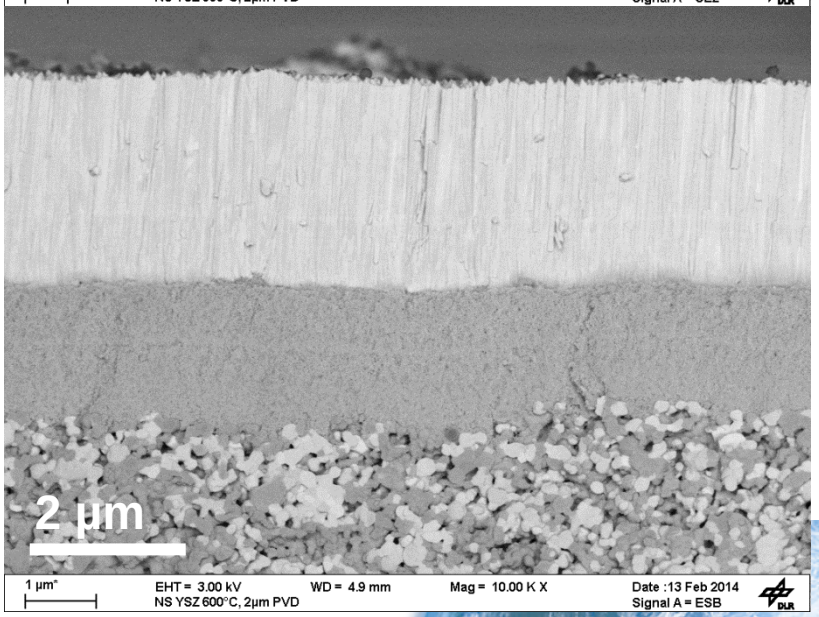
Gas-tightness is crucial for cell performance

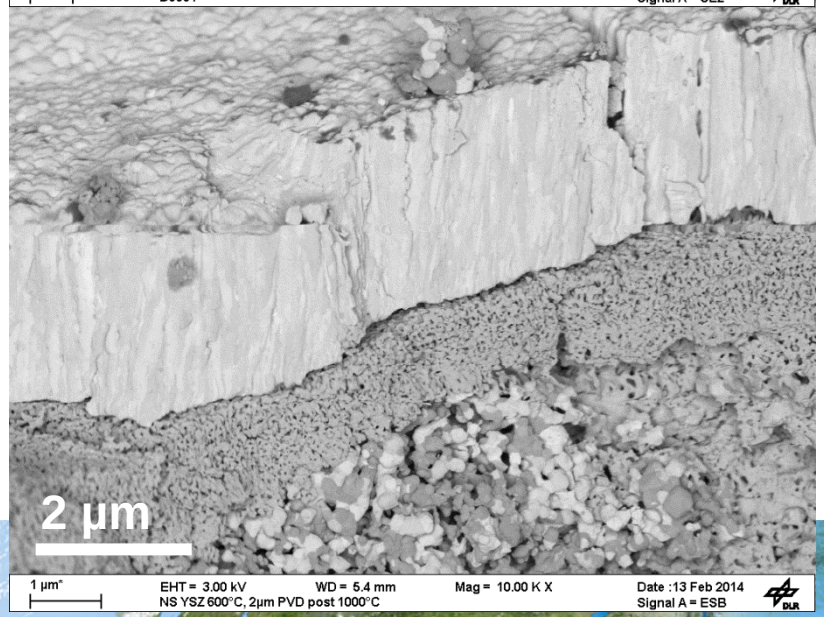
Thermal Stability of bi-layer Electrolyte

Thermal Treatment @ 1000ºC on Half Cells with PVD GDC









Cell processing route with graded layer strcuture and PVD electrolyte

substrate

Impregnation

1000° C

anode

screen printing

1000° C

YSZ

Dip-coating

600-1000° C

GDC

PVD

Dense electrolyte

cathode

screen printing
wet powder spraying

solid oxide fuel cell

Challenges:

- Defect-free anode layer
- Adhesion of layers
- Thermal stability

Conclusion

i. Half cells have been fabricated on substrates consisting of NiCrAl alloy foam as structural support and impregnated LST ceramic as anode material.

ii. Thin-film YSZ-GDC bi-layer electrolytes were made of dip-coated 1 µm thick YSZ layer and 2 µm thick PVD GDC layer.

iii. Despite the thin electrolyte, the leakage rate of the half cells with thin-film YSZ-GDC bi-layers has been measured as low as $7x10^{-4}$ $(hPa\ dm^3)/(s\ cm^2)$, demonstrating an good gas-tightness.

iv. Further optimization and electrochemical tests of the cells will follow in future work.

v. Potentials for other application fields requiring low ASR at low temperature: SOECs, co-electrolysis, methanation, and etc.

Acknowledgements

The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) for the Fuel Cells and Hydrogen Joint Technology Initiative under grant agreement No. 303429 (Project EVOLVE).

Thanks for Your Attention